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ABSTRACT

Presented is a summary report of the American experiments conducted on the Soviet Cosmos 782 satellite in November and December, 1975. Each of the four passive and seven cooperating experiments developed by the U.S. National Aeronautics and Space Administration (NASA) are reviewed. (SI)

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NASA Facts

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American Experiments on Cosmos 782

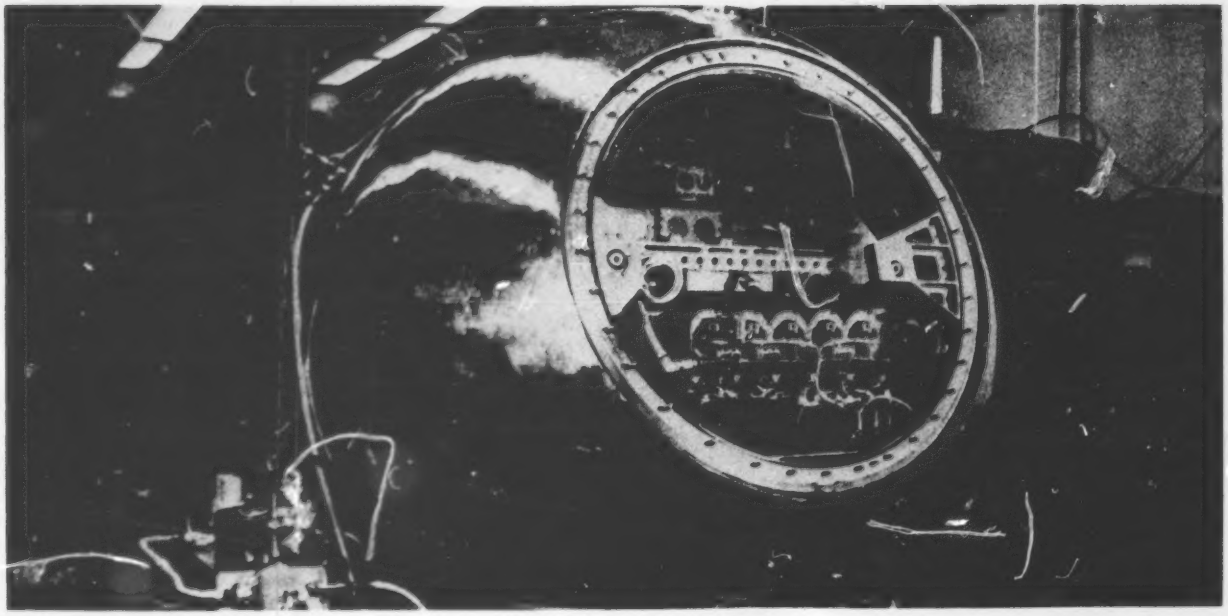


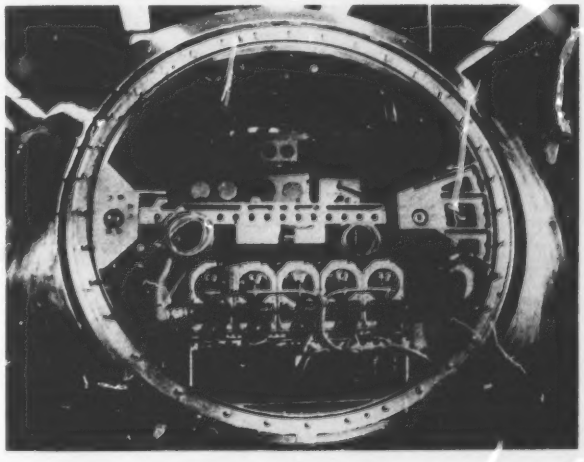
Figure 1. The Cosmos 782; photograph of the synchronous control spacecraft—a mock-up of the actual spacecraft—which was used to run groundbased simulated flight in which animals and test subjects were used as controls for the actual flight animals: (a) a general view of the spacecapsule, (b) a close-up of the interior. In this mock-up the flight environment was duplicated except for weightlessness.

Since 1975 American and Soviet scientists have been cooperating in a biological satellite program involving the flight of U.S. experiments on U.S.S.R. unmanned spacecraft. Cosmos 782 (Figure 1), the first of these satellites, was launched November 25, 1975, and was recovered safely 19 days later. Analysis of the scientific findings, some unexpected, is expanding the base of biological knowledge.

Cosmos 782 carried four passive experiments developed by the National Aeronautics and Space Administration. They required only stowage aboard the Soviet satellite. Seven other U.S. experiments provided for analysis of tissues supplied by Soviet investigators from their own experiments.

The NASA developed experiments were hand carried to Moscow. There they were turned over to Soviet technicians who had been provided with step-by-step instructions on how to handle the experiments before launch and after recovery.

The recovery tested men and equipment. The capsule returned to Earth in a howling blizzard. A Soviet mobile laboratory was airlifted to the re-



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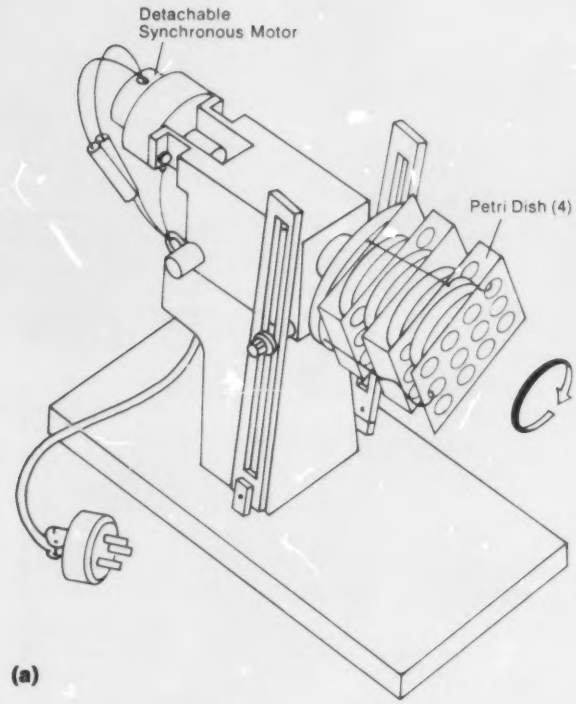
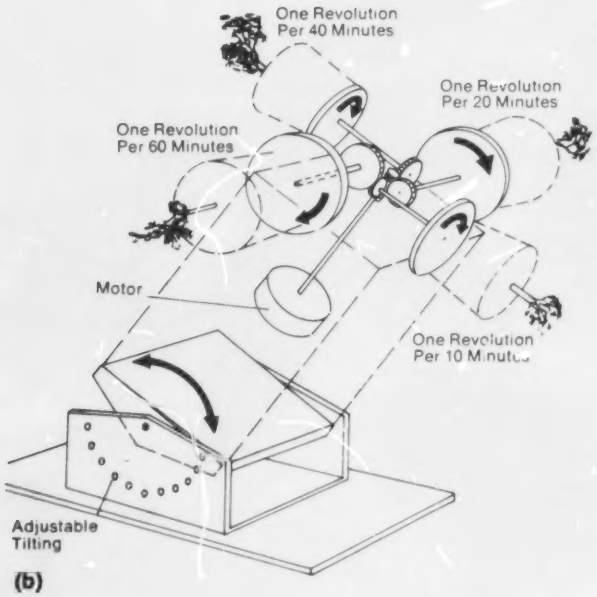


(a)



(b)

Figure 2. Experiments with the clinostats have shown that plant growth can be changed by exposing the plant to a constantly changing gravity field that simulates zero-g.
(a) shows a simple clinostat and how petri dishes or a plantpot can be attached for an experiment.
(b) shows a more complicated clinostat with heads geared to rotate at different speeds.

covery site by giant helicopter to service the space capsule. This laboratory consisted of a van and two large tents. Soviet technicians battled 70-knot winds and subzero temperatures to quickly erect one of the tents over the space capsule.

All experiments were carefully unloaded and transferred to a second tent in which a temporary laboratory was set up. There Soviet technicians did whatever was needed to safeguard the experimental subjects—fish, plant cells and tissue, flies, and rats—for the journey to Moscow and from there to the various scientific investigators.

Despite the terrible weather, the biological materials were prepared and returned to Moscow within 34 hours of the landing. Seven U.S. scientists already were in Moscow to receive their samples. They sent some samples immediately, by courier, to the United States and worked on others in Moscow first.

The scientific results were significant; some surprising, others expected. While certain changes to bone structure, blood, and hormones were confirmed, space flight did not seem to be very stressful to rats, minnow embryos, fruit flies, or plant cells and embryos.

The U.S. Experiments

Two of the U.S. experiments looked into the effects of weightlessness on sensitive plant systems. A third experiment, with fish eggs, checked development of embryos and looked for abnormalities in their balance organs, continuing work started in NASA's Skylab. A fourth experiment sought better information about cosmic ray dosages in space.

Effects of Weightlessness on Plant Tissue

When scientists simulated weightlessness by rotating plant tissue in a clinostat (Figure 2) they found that Crown Gall Tumor, which grows on carrots, grew more rapidly. This was expected on the basis that weightlessness would allow more efficient mixing of enzymes responsible for metabolic activity. In the Cosmos experiment some infected carrot slices were exposed to weightlessness while others were placed on a centrifuge (Figure 3) within the spacecraft to simulate gravity. Stationary and clinostated control samples remained on the ground.

Enzymatic activity differed considerably, as expected, between the weightless samples and the centrifuge samples within the spacecraft, and both had higher activity than the ground samples. The experiment demonstrated that a clinostat can produce on the ground the same enzymatic effects as weightlessness, an important result for planning experiments in school laboratories.

However, a big surprise was that the mass of the tumors in the weightless samples was significantly smaller than in the samples exposed to centrifugation on board the spacecraft. This is the opposite reaction to that predicted from previous

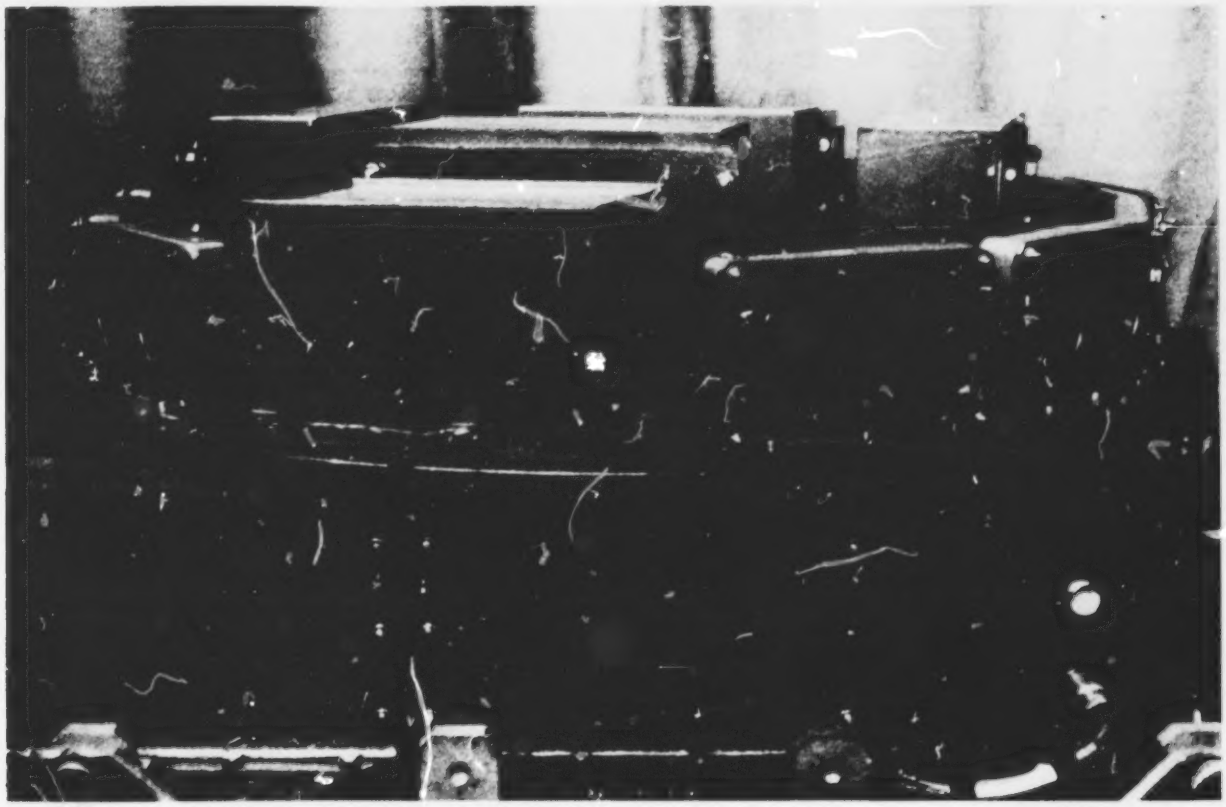


Figure 3. Close-up view of the centrifuge used in flight to simulate gravity in the space environment. Three U.S. experiments were mounted on this centrifuge as well as on the stationary plate (where they experienced weightlessness) which is below the centrifuge disc.

Earth-based gravity-compensated experiments. These results are unexplained and will be checked further in space. A school science project might be to check this effect with the use of a clinostat.

Effects of Weightlessness on the Ability of Plant Cells to Develop

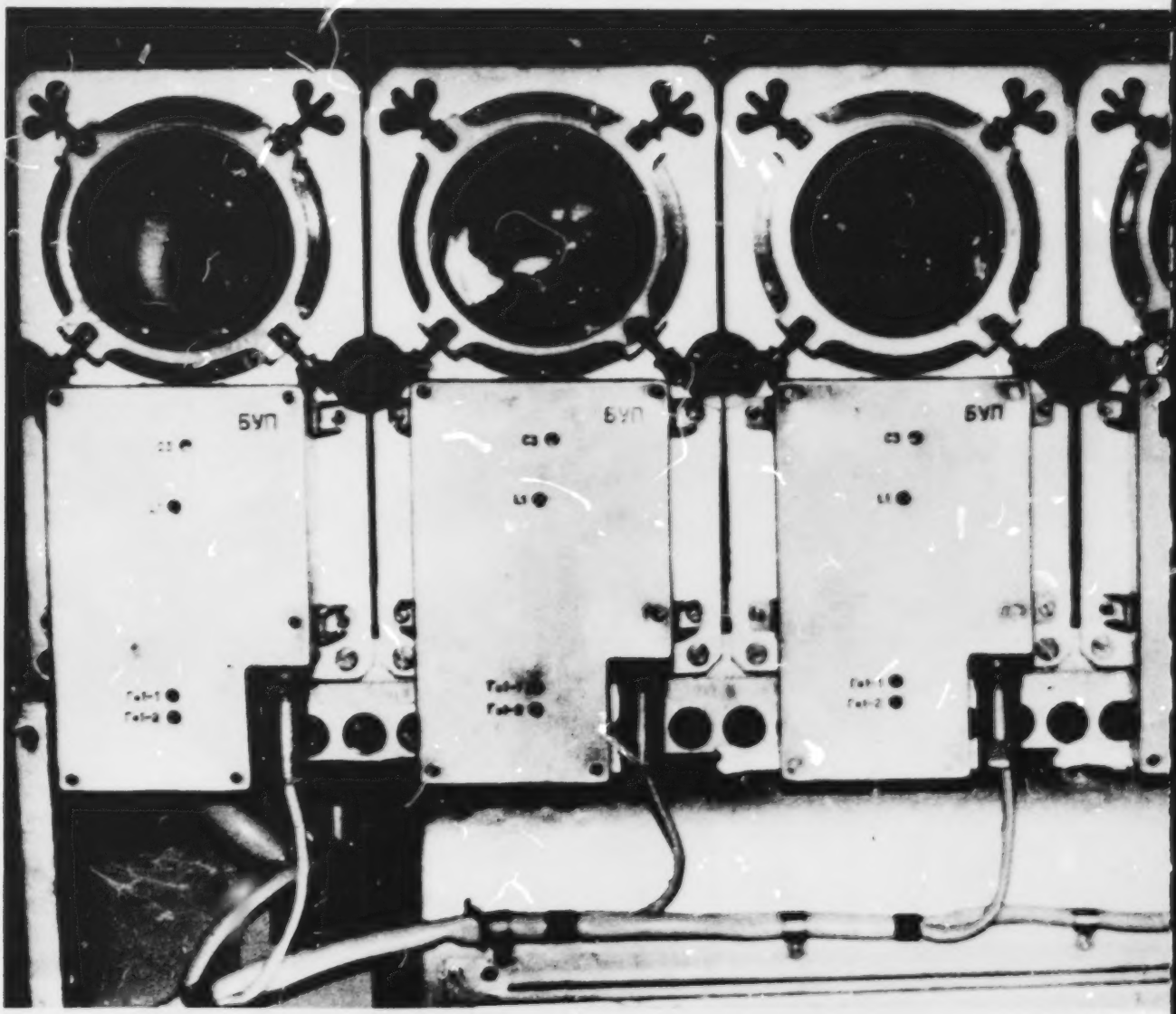
This experiment was designed to test whether plants that develop from single cells (namely fertilized eggs) could do so normally under conditions of weightlessness. This cannot be done with seeds because the embryos they contain already have passed through early critical stages of development. They contain, in fact, miniature plants with pre-formed growing regions of shoot and root and very large numbers of cells. While, ideally, one might start with fertilized eggs it is very difficult to do, especially in the large numbers needed. Instead a system based on cultured body (somatic) cells of carrot was used. Such cells were known to be capable of developing into embryos and plantlets. These cells, termed totipotent, after appropriate pre-culture, could develop within 20 days in a semi-solid medium in small petri dishes, into large numbers (about 2000 per dish) of carrot plantlets. The experiment exposed such dishes to weightlessness and to gravity (on a centrifuge) in space with appropriate control samples on the ground.

The experimental results showed that space flight and weightlessness seemed to have no adverse effects on the formation of embryos and the development of their organs.

Many of the plantlets originated in space were subsequently grown to maturity on Earth. However, since only one "generation" from cells to plants was studied in space, the question remains whether "successive generations" of plantlets could be successfully reared in space. This problem has importance for both space biology and "space agriculture" with flowering plants. It is hoped that this question will be submitted to further testing in space.

Development of Fish Embryos under Weightlessness

Two earlier experiments on Skylab and Apollo-Soyuz evaluated the effects of weightlessness on embryos at different stages of development of the minnow (Fundulus). No abnormal development was observed. Although the experiment on Cosmos experienced some technical problems, results appear to confirm the earlier experiments. Weightlessness actually may have beneficial effects and



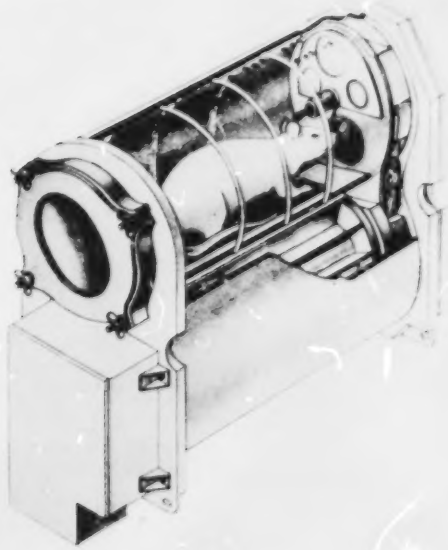
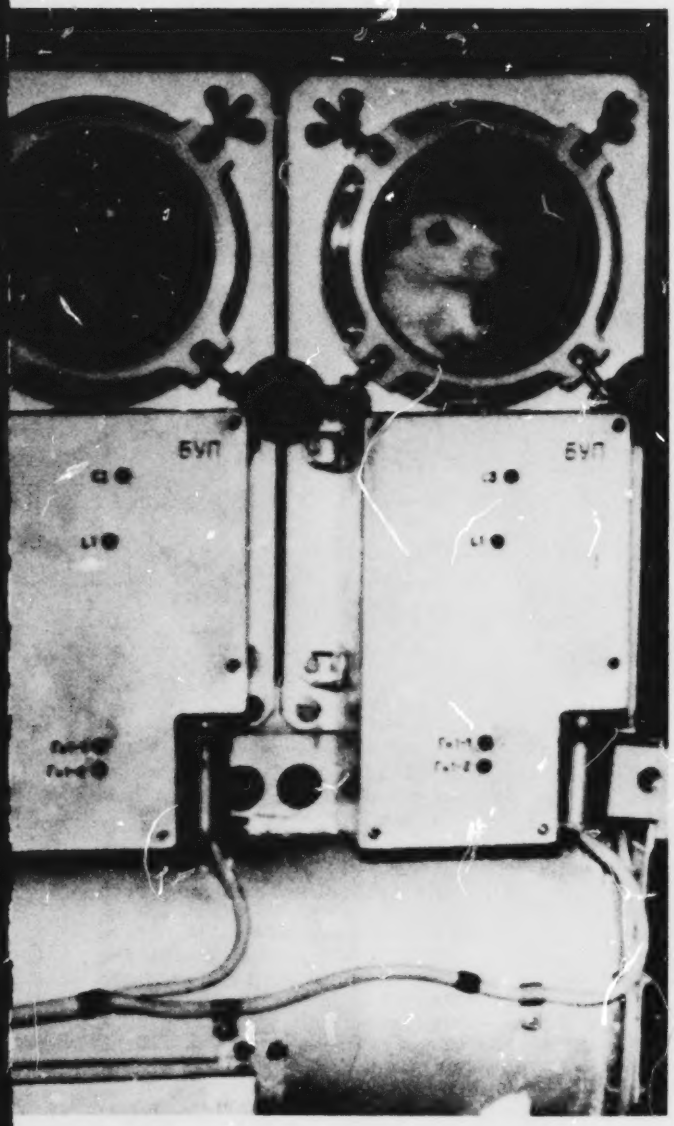


Figure 4. Close-up view of the "rat block" which was the caging system for the animals flown in Cosmos 782. Each block housed five rats and contained their food, water and waste removal system as shown in the cut-away view. Each cage was also individually lighted.

help embryonic development—the fish returned from space seemed healthier than the control fish left on the ground. There also was no detectable degradation of the balance organs.

Radiation Dosimetry Experiment

The flux of cosmic rays as measured by this experiment was about 21 percent higher than that previously measured by U.S. experiments in low inclination orbits. Cosmos 782 had an orbit inclined 62.8 degrees to the plane of the Earth's equator. In this more steeply inclined orbit radiation flux was expected to be greater.



The information gathered is important in determining the relevant physical parameters of the particle radiation environment inside the Cosmos 782 spacecraft. The data will be useful in planning subsequent Cosmos missions and assessing the hazards of particle radiation for long duration manned space flight.

Experiments with Soviet Supplied Material

Rat tissue and Drosophila (fruit flies) were prepared by Soviet and other scientists for analysis by U.S. experimenters since these formed part of major Soviet and international experimental packages (Figure 4). The analysis of rat tissues looked for changes in the animal's endocrine system and the effects of weightlessness on bone and on blood cells. The experiment with fruit flies was designed to find out if weightlessness affects the life span of the insect.

Stress Effects on Stomachs of Rats

Rats develop stomach ulcers rapidly when placed under stress in a laboratory. The stomachs of the rats flown in the satellite were inspected to find out if they had developed ulcers. No ulceration or mucosal lesions were found. However, the rats had received antibiotics before flight and had been fed well during flight; both circumstances mitigate ulcers. Additionally, a rat's stomach heals rapidly without scars. If ulcers had developed from launch stress they might have healed before the tissue was examined.

Effects on the Immune System of Rats

The human body protects itself in several ways against infection. T-lymphocytes are part of the immune system. They are derived from stem cells in bone marrow. Some preliminary evidence from manned space flights was that such cells are affected and lose some of their competency. The rats flown in Cosmos 782 were immunized with a specific antigen before their flight and cells were tested afterward. Contrary to expectations, the cells seemed to be more competent after the flight. Soviet experiments with B-lymphocytes appear to confirm the U.S. results.

Life Span of Red Blood Cells

Astronauts experienced during space flight a reduction in their total red blood cells. This Cosmos experiment was directed toward detecting a reduction in the mean life span of the red blood cells of rats (normally 62.4 days) as a possible cause of their reduction. A significant decrease of 5.45 percent, to a mean of 59 days was discovered. An increased rate of destruction was also detected. There is still no clearcut explanation of why. The experiment will be repeated to obtain more definitive information.

Effects on Bone Formation

Bone is a dynamic tissue and is affected by weightlessness, immobility, and the loads placed upon it. Inactivity through confinement, immobilization or paralysis causes a significant reduction in amount and quality of bone. The way in which the health of bone is affected by the environment is very important to the general health of people in their everyday work and when they are confined or restricted as a result of accident or sickness as well as to manned space flight. The conditions of weightlessness in space offer unique opportunities to study the effects of environment upon, and to test theories about, bone structure.

Exciting new results came from the Cosmos experiments.

An innocuous chemical injected into the rats before flight labeled their bones wtih a long-lasting phosphorescent readily seen under a microscope.

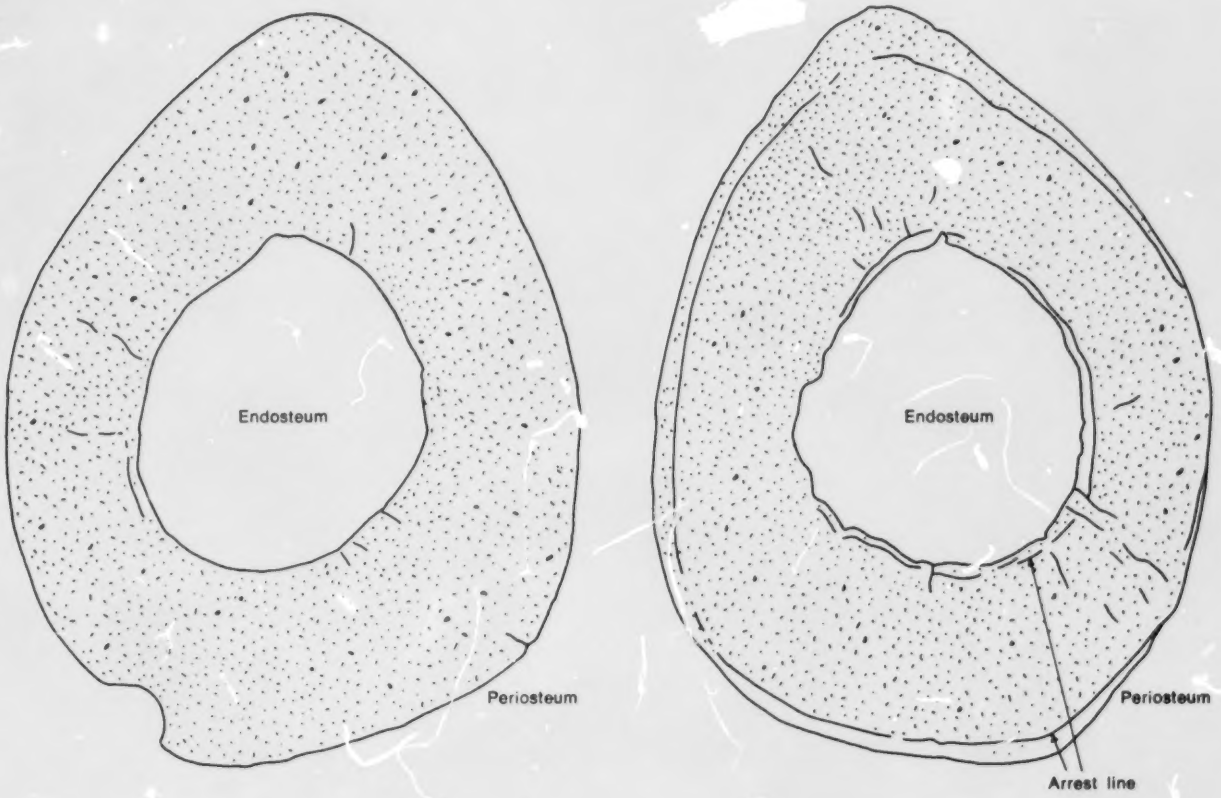


Figure 5. The effects of weightlessness on bone growth show as a growth arrest line in the layers of endosteum and periosteum. The drawing at the left is from a micrograph of a control rat with normal growth. The drawing on the right shows the arrest line in the bone of a rat that experienced 19 days of zero-g in Cosmos 782. The original photomicrographs were made by E M. Holton, NASA Ames Research Center and D. J. Baylink of the Veterans Administration Hospital, Seattle, experimenters on Cosmos.

This label was used to determine how much bone was formed.

Striking effects on bone formation were found; all the measurements made on the flight animals immediately after the flight were significantly less than those made on the animals of the control groups. An arrest line (see arrows on Figure 5) was found at both the endosteum (inner layer of the bone) and the periosteum (outer layer) of the flight animals. This suggested to the experimenters that bone growth ceased completely during the space flight.

However, by 25 days after return to Earth, the flight animals exhibited a significant increase in bone formation. This suggests a rebound effect following return to normal gravity.

The results are important because they may ultimately be applied to devising exercises to stress bone and prevent it deteriorating under weightlessness or immobility. At present, exercises used in space tone muscles only. If bone strengthening exercises can be discovered they might also be beneficial to people confined to bed because of sickness or injury.

Cosmic Ray Tracks in Eye Tissue

Astronauts in space reported seeing flashes which were attributed to the action of cosmic rays passing either through the retina or the visual centers of the brain. Eyes of rats carried on Cosmos were examined to seek cell damage that might be evidence of cosmic rays. No such tracks of cosmic rays were found. Most of the eye tissue was normal, thereby indicating that space flight for this period is quite safe as far as detectable damage to the eyes by cosmic rays is concerned.

Aging of Fruit Flies

Terrestrial life forms evolved in Earth's gravity which probably played some role in shaping their structure and function. While earlier experiments indicated that insects could reproduce normally and their young develop normally under conditions of weightlessness, some tests on clinostats indicated that the aging process of Drosophila was sensitive to a changed environment.

A Cosmos 782 experiment looked for such effects. Experimental flies were placed in the spacecraft as a 4-day old larvae at time of launch.

An equal number of larvae was placed in the centrifuge aboard the spacecraft to experience the same environmental effects of space flight but with simulated gravity. Two other groups of larvae remained on the ground; one in a simulation of the spacecraft, the other in standard laboratory conditions.

The larvae were exposed to 7 days of weightlessness before adulthood and then 13 days as adult flies. After their return to the terrestrial laboratory body weight, vitality (geotaxis and mating), general morphology, degenerative changes associated with age, glycogen content of the thorax, and life span were assessed.

The flies exposed to weightlessness were practically identical to the other flies. Only a few minor structural differences were found: better preservation of some cells and less intracellular body weight accumulation. The flies exposed to weightlessness did not live longer than their counterparts on the ground. However, there was a decrease in the tendency of the satellite flies to fly up against gravity (negative geotropism) and they had a decreased mating competence. The latter might have resulted from shock of launching rather than weightlessness. One cause suggested was damage to wings, since the ability to move the wings is essential to the male mating role in courting a Drosophila female.

Editor's Note: In the summer of 1977 the United States participated with the Soviet Union for the second time in placing life science experiments on a Cosmos spacecraft. There were six experiments: a study of the genetic and aging process of Drosophila in zero-g; a study of the effect of weightlessness and centrifugation on the life span of red blood cells in rats; a joint radiation dosimetry experiment; an examination of the retina of rats by electron microscopy to assess damage, if any, due to high energy particle radiation; an analysis of liver tissue of rats for key metabolic enzymes involved in the conversion of carbohydrates to lipids; and a study of the effects of weightlessness and centrifugation on bone growth in rats.

Sources for Background Information

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Biomedical Results of Apollo: NASA SP-368, GPO 003-000-00628-4, Washington, D.C., 1975, $13.25

Skylab Experiments; Vol. 4 Life Sciences, NASA Educational Publication, EP-113, Washington, D.C., 1973

Gravity Compensation and Crown Gall Development; T. R. Wells and R. Baker, Nature, v.233, 1969, pp.734-735

Light Flashes Observed by Astronauts on Apollo 11 through Apollo 17. L. S. Pinsky et al., Science, vol. 183, March 1974 pp.957-959

Two NASA films are available: **Conservation Laws in Zero-G,** and **Zero G.**

Student Projects

Environmental Effects on Fruit Flies

Obtain three populations of at least 100 each of *Drosophila melanogaster* larvae each about the same age. Incubate these three populations separately at 21°C for several weeks, one under each of the following environments;

a) normal laboratory conditions,

b) simulated zero-g on clinostats (See Figure 2) with horizontal axis.

c) under simulated increased gravity of 4xg in a centrifuge.

Provide the necessary food during the incubation, a continuous light of moderate intensity, and an atmosphere of 40 percent humidity.

Check the following parameters on each section of the population:

a) *Negative geotaxis.* Place a layer of soft plastic on the bottom of a glass stoppered volumetric cylinder of 250 ml. Put about 50 flies in the flask and cause them to fall to the bottom by tapping the cylinder against a rubber mat. Then count the number of flies that fly upward past the 250 ml mark in 20 seconds.

b) *Average body weight.* Take a sample of 20 flies from each group and weigh them after etherization. Do this at the middle and the end of the incubation period.

c) *Longevity.* Measure life span of about 30 flies from each sample in terms of the days since hatching from the egg laying that provided the larvae.

Questions: Are there significant differences between flies of the three populations for any or all of the three parameters measured? Compare your results with those obtained on Cosmos.

Extension: The experiment can be made more comprehensive in terms of environmental effects by repetition at different temperatures and in different magnetic fields (see next project).

Magnetic Fields

Life evolved on Earth in a magnetic field. Students can develop projects to test the effects on living systems of varying magnetic fields by use of a Helmholtz coil to increase the field and a mumetal box to screen from the field. The terrestrial field can also be countered electromagnetically if a

mumetal box is not available.

Both plant and cell cultures can be tested. These effects are still relatively unexplored. A rough demonstration can be prepared to show possible effects. Place a sheet of stiff paper on a flat metal plate. On top of the paper place a group of small circular magnets, some colored differently so that a pattern can be seen. The magnets group together simulating a complex biological molecule. Now lift the paper away from the metal plate; the magnets regroup into a different pattern. Atoms may similarly regroup in biological molecules as the magnetic field passing through a living system is changed. Note: In making experiments on the effects of magnetic fields on living systems care must be taken to avoid using magnetized tools or magnetic materials. Use plastic tweezers and make sure that the microscope is modified to have non-magnetic materials.

(All photos supplied by Soviet Institute of Biomedical Problems)

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